SALMON GENETICS RESEARCH PROGRAM

ANNUAL REPORT 1990/1991

Government of Canada
Gouvernement du Canada

Fisheries and Oceans
Pêches et Océans

National Research Council
Conseil National de Recherche

ATLANTIC SALMON FEDERATION
FEDERATION DU SAUMON ATLANTIQUE

New Brunswick Salmon Growers Association
l'Association des Producteurs de Saumon du Nouveau-Brunswick

New Brunswick Department of Fisheries and Aquaculture
Ministère Pêches et Aquaculture du Nouveau-Brunswick

COVER

Top photo - David Clark prepares to release a salmon (Photo courtesy of Bill Taylor)

Bottom photo - Mike Groom handles a broodstock candidate from a sea cage (Photo courtesy of Greig Cranna)

Cover design - Jane Cleaves
SGRP logo - Arthur Mackay

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93-02501/

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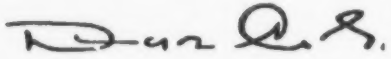
PREFACE

Management and enhancement of Atlantic salmon is always a dynamic and interactive process requiring partnerships and collaboration among players; so does salmon research.

The Salmon Genetics Research Program is an excellent example of government-private sector cooperation. Assisting the Federation with both the SGRP's funding and direction, the latter through membership on the Steering Committee, are the Department of Fisheries and Oceans, the NB Salmon Growers' Association, the NB Department of Fisheries and Aquaculture, and the National Research Council of Canada. Deserving special mention are the members of the Scientific Advisory Committee (see page 29) whose special expertise has helped to maintain the SGRP's scientific preeminence.

This report covers the highlights of the SGRP for the period, April 1, 1990 to March 31, 1991. Further information on the research program can be obtained by contacting the chief scientist of the SGRP, Dr. Gerry W. Friars, at the address noted above.



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Conservation for a Bright Future

INTRODUCTION

Seventeen years of progress in the Salmon Genetics Research Program (SGRP) have yielded an improved understanding of the Atlantic salmon *(Salmo salar)*. Genetic effects on the growth and development of this fish, in both the fresh and seawater stages of its life cycle, have been demonstrated in a wide array of traits. The interplay between genetic and environmental effects is of paramount importance in the adaptation of this species to its natural habitat as well as its performance in culture.

The trends in the return rates of two gene pools derived from crosses of different river stocks have shown similar results. Improved returns resulted after random mating allowed a mixing of the genes, technically known as an approach to genetic equilibrium. These results suggest that the mating system is important in the fostering of selection response - a breeding principle that appears to hold where return rate is measured on smolts released to sea.

The SGRP involvement as a primary breeder for the aquaculture industry has allowed the controlled investigation of the genetics of characteristics, such as smoltification (a shift from freshwater to seawater adaptation), grilsification (ability to become sexually mature after one sea winter, in contrast to multiple-sea-winter salmon) and growth to different ages. Tests of stocks, developed for cage culture, have demonstrated genetic gain from selection in economically important traits.

Many of the advances in knowledge have been demonstrated to be interchangeable between wild and domesticated stocks. Also, preliminary studies indicate that genetic manipulation at the chromosome level may play a role in the production of superior aquaculture stocks. Simultaneously, the sterility associated with triploidy can serve to curtail the danger of cage escapees mating with wild stocks and upsetting the genetic balance in natural habitats.

Cooperative research involving universities and governments continues to enhance the efforts of the SGRP. The expertise available from these sources, coupled with the efforts in the SGRP, accords a synergism where the outcome is greater than the sum of the parts from the separate resources.

TRENDS IN RETURN RATES OF STOCKS RELEASED TO SEA

G.W. Friars[1]

The disentanglement of genetic and environmental effects on the ability of stocks to migrate to sea as smolts, and return as sexually maturing adults, has been the subject of continuing research in the SGRP over the years. The

[1]The affiliations of the contributors to the various sections of this report are listed under staff or as cooperating researchers on pages 29–31.

collection of eight different river stocks, for the production of smolts that were reared in and released from the same freshwater environment at the Salmon Research Centre, allowed the systematic assessment of the heritable components of different traits. Ability to become ready for sea water by about 18 months after the early embryo stage (S1 smolts), capacity to grow at sea and the skill to return from sea either after one sea winter (grilse) or after multiple sea winters (MSW) are important attributes that have been found to be heritable. The proportion of grilse in the stocks described in this study was about 84.3 percent.

Systematic crosses of these river stocks formed the basis for the synthesis of two gene pools, in consecutive year classes (SGRP Annual Report 1985/86). The return rates of smolts released to sea from these two gene pools was in the range of .59 to .68 percent (depicted as 1981 and 1982), before cross-bred parents were involved. The next generation, which returned in 1984 and 1985, arose from parents that were predominantly crossbreds. The return rates declined dramatically to .06 and .17 percent (Figure 1). Individuals that were full brothers and sisters of the fish that returned at a low rate were reared in sea cages. Random matings of the cage stock produced the smolts that were released and returned in 1988 and 1989.

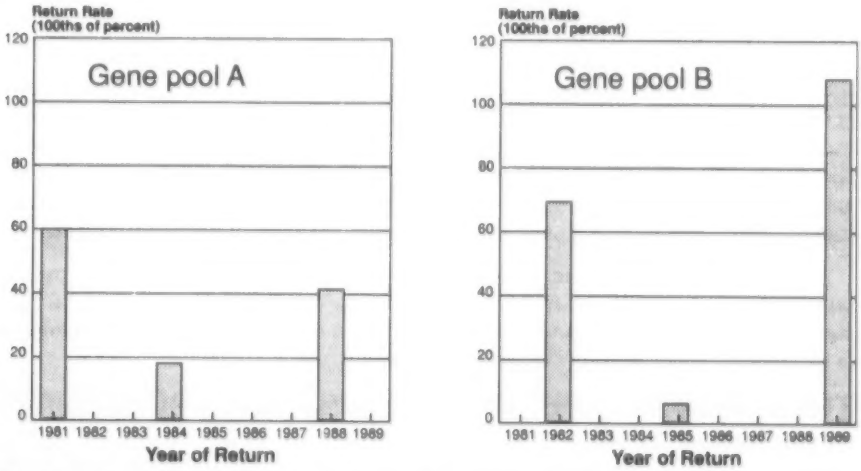


Figure 1. Return rates of two gene pools comprised of two-sea-winter salmon pooled with grilse in the previous year.

The improved return rates of .41 percent in 1988 and 1.10 percent in 1989 represent significant recoveries. These trends suggest that the break-up of gametic disequilibrium, as represented by the gene combinations in the crosses,

may play an important role in the formation of gene pools, where appropriate combinations of genes display an ability to increase return rates.

Although other factors such as improved smolt quality may have contributed to the increased return rates, two important points lend credence to the genetic recombination hypothesis. Firstly, the repetition of the results in two separate gene pools following random mating is worthy of note. Secondly, these recoveries in return rates were experienced in years when neighbouring rivers in the Inner Bay of Fundy, that also have stocks with high grilse rates, were experiencing relatively low rates of return.

Comparison of Atlantic Salmon Early Growth Between Individual Family Rearing and Mixed Family Rearing Using DNA Fingerprints to Trace Parentage

C.M. Herbinger, R.D. Doyle, G.W. Friars and J.K. Bailey

This project was initiated in November, 1989. It will compare the early performance of 12 full-sib families when reared in isolation to that observed when the families are reared together. DNA fingerprints will be used to separate the 12 full-sib families in the mixed groups. In June, 1990 growth data and blood were collected. The data will be analyzed when enough single locus fingerprinting probes are available to trace the pedigree of the mixed family fish.

Future experiments involving DNA fingerprints will be used in the detection of changes in the gene pool of fish returning from sea, in contrast to that of the released smolt population that will give rise to returnees.

Vaccinated Versus Non-Vaccinated Returns of SGRP Fish from Sea

C.G. Soto and G.W. Friars

On April 11 and 12, 1989, when water temperatures were approximately 3.5°C, approximately 7,455 individuals from about half of the 95 families spawned at Mactaquac in 1987 were vaccinated for furunculosis and vibriosis, using immersion. These fish were adipose-fin clipped, whereas the contemporary unvaccinated controls were not clipped. Samples of 200 control and 200 vaccinated fish were challenged with a virulent *Vibrio anguillarum* isolate. The results indicated significant protection in the vaccinated fish.

The results of the return rates from the remainder of these fish, released on May 23, 1989, were expressed in the grilse that returned in 1990. Of the 42 returned grilse for which clip data were available, 30 had not been vaccinated and 12 had been vaccinated. The difference was significant, as revealed by a chi-square test ($P<.01$). The data suggest a negative association between vaccination and survival. Results of research done elsewhere vary with respect to

agreement with these findings to date. Similar results were obtained with smolts at the Mactaquac site on the Saint John River. The salmon returns of this release, together with data from another year-class released in 1990, will allow an observation of the ability to repeat this result.

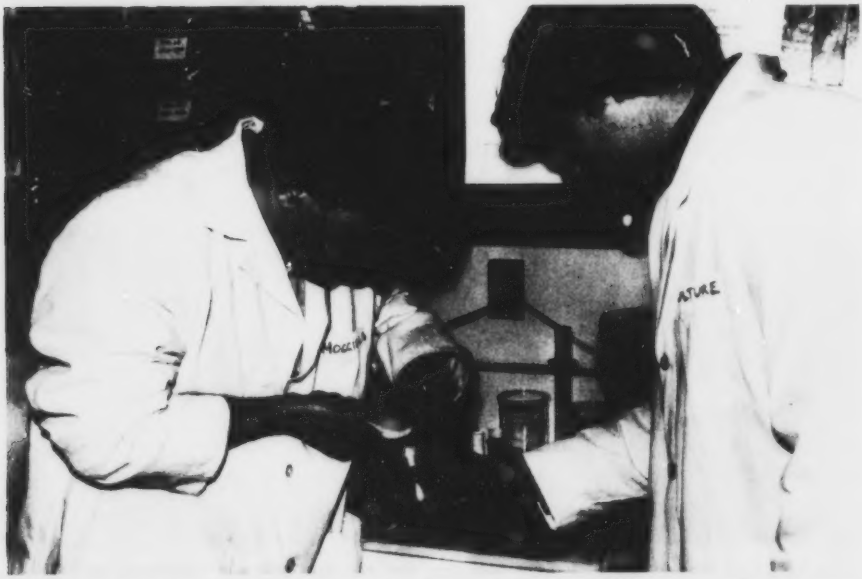
Dr. C.M. Herbinger of Dalhousie University cooperates in SGRP spawning procedures related to DNA fingerprinting.

Milt Quality in Relation to Embryo Survival in Preliminary Cryopreservation Studies

R.D. Moccia, A.J. Harrington, G.W. Friars and F.M. O'Flynn

The use of frozen semen technology has become an important tool in animal breeding. Cryogenics allows the preservation of genes from superior individuals. The threats to wild stocks of Atlantic salmon, associated with acid rain and other forms of pollution, has heightened interest in the formation of gene banks for this species. The use of frozen sperm offers one approach to such preservation, particularly where the technology for freezing eggs and embryos is less developed than that for male gametes.

In the Fall of 1990, the SGRP, in co-operation with the University of Guelph, began studies on semen preservation. Samples of milt were preserved from three grilse kelts and 16 grilse. The reconditioned kelts were available because of attempts to widen the gene pool, when they were crossed with two sea-winter females from the same smolt release. These samples were obtained during the spawning of sea-run stock and shipped to the University of Guelph. Prior to freezing (the effects of which will be evaluated later), milt quality was assessed. The relationship of the milt-quality traits is summarized in Table 1.



Professor Rick Moccia and Technician Steve Naylor of the University of Guelph collect milt from a SGRP precocious parr.

Table 1. Proportion of variance in embryo survival to the eyed and hatch stages attributable to spermatocrit, sperm density and motility.

Milt quality variable(s)	Proportion of variance	
	Eyed stage	Hatch stage
Spermatocrit	.08	.12
Density	.12	.12
Motility	.13	.12
Spermatocrit + Density	.15	.18
Spermatocrit + Motility	.18	.20
Density + Motility	.16	.15
Spermatocrit + Density + Motility	.19	.21

The proportions of variance in the survival rates, attributable to the milt quality traits, are low and insignificant (P>.05). However, it must be remembered that the samples had been shipped on ice and were about 24 hours old when assessed. The higher relationship of spermatocrit to survival at the hatch, as opposed to the eyed stage, may be spurious. Although these results indicate poor relationships between milt quality and embryo survival, fresh milt should show stronger correlations. Similarly, cryogenic treatment may need to be applied to fresh milt.

Technician Fred DeSaulniers assists Dr. Robert Hawes, visiting Professor, University of Maine in the examination of a SGRP breeder candidate for an aquaculture stock. (Courtesy Greig Cranna)

DEVELOPMENT OF AQUACULTURE STOCKS

Some of the information in this section has been released in the third Newsletter to New Brunswick salmon growers.

Flow of Genes from Mactaquac Through the SGRP to Industry

G.W. Friars

The Saint John River stock has performed well under conditions in the Southwest Bay of Fundy, principally because of a low incidence of grilse. The early introductions of this stock from the Mactaquac and Saint John hatcheries to the Bay of Fundy cage-culture industry represented a very small number of parents. In light of this shortcoming, four year-classes, to cover each year of a four-year generation interval, have been sampled from the Saint John River (Table 2). These year-classes each involve 48 to 50 single-pair mating to counteract inbreeding in later generations and to allow a broad genetic base on which selection can act. The shortage of males in the 1987 spawning season necessitated the mating of 21 sires with 98 dams in Strain 87JC, an approach that also allows only a low level of inbreeding, similar to those of the other year-classes.

Table 2. Status of four year-classes as of February, 1991.

Strain	Life Stage and Location
84JC	In first sea winter with multiplier growers and at the Atlantic Salmon Demonstration and Development Farm (ASDDF)
87JC	In second sea winter with multiplier growers and at ASDDF
89JC	Department of Fisheries and Oceans (DFO) hatchery - Saint John
90JC	Fry at Salmon Research Centre

The 84JC Strain has gone through one generation of domestication and selection was applied in 1988 (Table 3).

Although it takes 11 years (1984 to 1995) for a wide section of the industry to receive the benefits of one round of selection and domestication in commercial production, a second round of improvement will have commenced accumulation in 1992. Also, genetic gains in the other three year-classes (Strains 87JC, 89JC and 90JC) will have started to accrue before 1995. However, the superiority in the latter three strains (Table 2) will not be apparent until selection has been performed. The accumulation of selection gains is what will allow the industry to remain competitive with production from abroad in the future.

Table 3. Stages in the gene flow of a single strain (84JC) from Mactaquac to industry.

Year	Operation
1984	Eggs shipped from Mactaquac to Salmon Research Centre (SRC)
1986	Smolts to the Atlantic Salmon Demonstration and Development Farm (ASDDF)
1988	Spawning at ASDDF
1990	Smolts to multiplier growers (also repeat cycle at ASDDF)
1992	Eggs from multiplier growers to commercial hatcheries Eggs from ASDDF to SRC after second generation selection
1994	Smolts from commercial hatcheries to growers Smolts derived from a second generation of selection to multiplier growers
1995	Commercial fish marketed

Genetic Improvement of Atlantic Salmon for Aquaculture

J.K. Bailey

Broodstock for Strain 84JC were selected on the basis of a linear index which was used to estimate the breeding value of each potential parent. The index took into consideration a number of genetic parameters and the relative economic values of four different traits. The traits included in the index were fry length, percent S1 smolts, harvest length and length at sexual maturity. The index was designed to increase average values in all four traits.

In addition to the select smolts which were sent to the nine multiplier growers, approximately 7,500 pedigreed, select and unselected control smolts were transferred to two special sea-cage sites in the second quarter of 1990. The primary evaluation of this strain is being conducted on 5,000 fish at only one site, the ASDDF. The second site received 2,500 smolts strictly as a precautionary procedure, to provide a back-up source of select stock should some disaster or disease outbreak eliminate the fish at the ASDDF.

Analyses of growth and survival during the freshwater stage has been completed for both the control and select lines. A number of freshwater traits were examined and a positive response to selection was observed in nearly all cases (Table 4). The greatest responses were seen in the two traits under direct selection (fry length and percent S1 smolts). Responses in harvest weight, another trait in the index, will be observed in 1991. In addition, positive, indirect or correlated responses were observed for other important production traits. The magnitudes of the selection gains of the freshwater traits were as expected and substantiate the efficacy of the selection procedure.

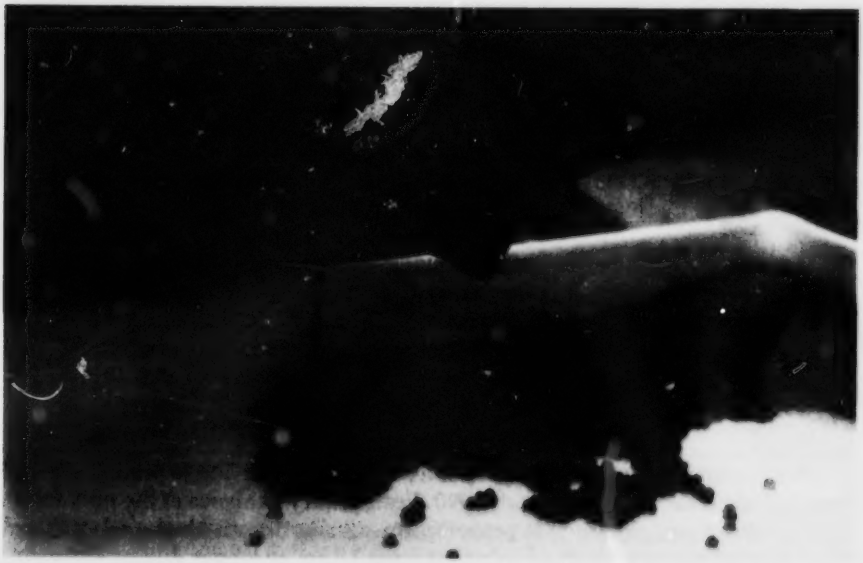
Table 4. Direct[1] and correlated[2] responses to index selection in the freshwater stage of Strain 84JC Atlantic salmon. Gains are given in standard deviations (SD) and are comparable among traits.

Trait	Control Line	Select Line	Gain (SD)
Egg volume[2] (mm^3)	104.8	108.0	.29
Survival[2] (%)			
to eyed stage	56.6	53.1	-.09
eyed to parr	31.9	52.8	.09
Fry length[1] (mm)	64.0	66.9	.43
Fry weight[2] (g)	2.9	3.3	.38
S1 smolts[1] (%)	44.6	53.6	.40
Parr length[2] (mm)	112.8	115.1	.24
Smolt length[2] (mm)	167.5	169.7	.16

Measurements on individual fish at the post-smolt stage were recorded ahead of schedule, during August, 1990. Preliminary analyses of the post-smolt data has been completed. The presumptive smolts from both the control and select line represented individuals that were 13 cm or longer during the grading process between late January and early March. This standardization tends to diminish the size difference between the two lines when they enter sea water. However,the select line showed a positive response in all but one case (Table 5). Post smolt growth measurements were taken after only three months in sea water and approximately 12 months prior to market age (the third trait in the index) and it is anticipated that these differences will increase as the fish age. The results to date are encouraging and are consistent with expectations.

Table 5. Correlated responses to selection for harvest and mature length in Strain 84JC Atlantic salmon post-smolts after four months in sea cages. Gains are in standard deviations (SD).

		Early Control	Early Select	Late Control	Late Select
Cage 9	Length (cm)	37.55	37.81	37.93	38.30
	Weight (kg)	0.62	0.63	0.64	0.65
	Gain (SD)				
	Length		.13		.15
	Weight		.11		.03
Cage 10	Length (cm)	37.23	37.77	38.03	38.21
	Weight (kg)	0.62	0.64	0.67	0.66
	Gain (SD)				
	Length		.27		.08
	Weight		.21		.07



Eggs are collected from and kept separate for individual females in breeding operations (Photo courtesy of Bill McMullon)

Artificial Selection Improves the Growth Characteristics of the Saint John River (SJR) Stock

A.R. Hanke

Currently, the Atlantic salmon aquaculture industry in the Bay of Fundy relies solely on SJR fish to stock their sea cages. Although these are superb fish under the present market conditions, future pressures will require a salmon stock with better growth characteristics if the industry wishes to remain competitive with producers from other areas. This improvement can be achieved in two ways: by seeking another naturally occurring river stock that performs better than SJR fish, or by improving the SJR stock using artificial selection techniques. The SGRP has opted for the second alternative while exploratory work progresses in other areas.

The SGRP is playing an active role as a primary breeder, supplying artificially selected SJR stock to the industry. In the last two years, a stock with a wide gene pool and another with a broad genetic base plus one generation of multiple trait index selection has been supplied to multiplier growers, who will produce eggs from parents of SGRP origin for the commercial hatcheries. In an effort to assess the benefits accrued in the stock from a single generation of

selection for improved harvest length, mature length, parr length and percent smoltification, the select stock was compared to the commercial stock at four multiplier grower sites.

The select and commercial fish were stocked in separate cages on each site as one year smolts, in the Spring of 1990, and were measured the following November after six to seven months of seawater growth. Although replicated pairs of cages were not used at each farm, the farms themselves represent four replicates of the lines. The length and weight of two hundred select and two hundred commercial fish was measured at each site. Due to an inequality in smolt size of the two stocks at the different sites, the November lengths and weights were adjusted to a common smolt size. A test of the effects of cage site and stock differences showed that the select stock was 50 g heavier ($P<0.1$) and .7 cm longer ($P=.12$) than the commercial stock (Figure 2).

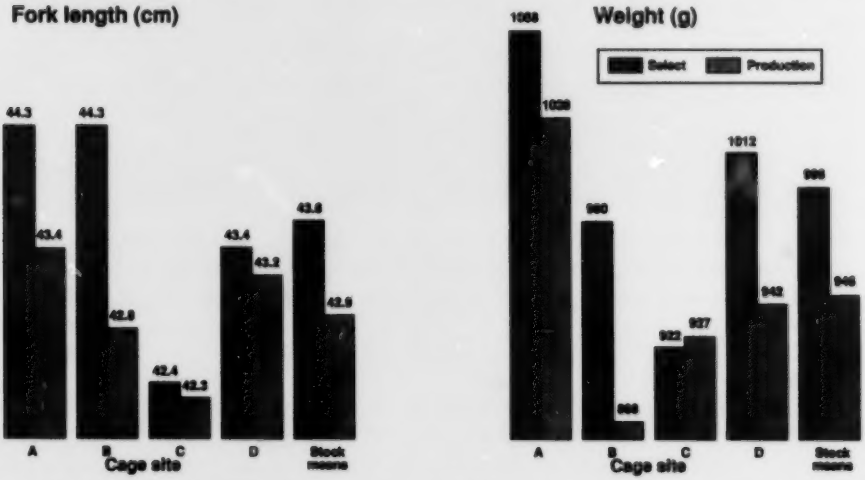


Figure 2. Size of select and production stocks in November after six to seven months of growth in sea water.

Significant differences among cage sites point to the variation in environmental conditions and/or husbandry practices found at each site.

The results from this study are encouraging. After only one generation of multiple-trait-index selection the selected SJR stock is showing gains in size that are superior to the commercial stock. With each subsequent generation of selection, the select stock is expected to improve with respect to its ability to compete in the international market place.

Strain 85XC

J.K. Bailey

The current generation of the Biotechnology Strain, now designated as Strain 85XC, was spawned in 1989. Control and select lines were established and the select parents were selected on the basis of a linear index. The selection technique was designed to increase parr size, percent S1 smolts, and harvest length simultaneously.

Separation into presumptive parr and smolts was completed during the Winter and smolts were sent to sea cages in the Spring of 1991. Smolting rate was exceptional in this strain, exceeding 90 percent overall.

The direct and correlated responses to selection, which were measured during the freshwater growth stage, are outlined in Table 6. The progeny of selected parents outperformed those of the control parents for all traits measured. The results to date are in line with the expectations for the selection procedures applied.

Table 6. Direct[1] and correlated[2] reponses to index selection in Strain 85XC. Gains are expressed in standard deviations (SD).

Trait	Control	Select	Gain (SD)
Eggs per female[2]	11525	13487	.69
Survival[2](%)			
Eyed stage	49.75	61.82	.24
Eyed to parr	69.75	75.13	.28
Fry weight[1] (g)	1.00	1.06	.27
% S1 smolt[1]	89.08	91.13	.27
Smolt[2]			
Length (cm)	17.62	17.93	.10
Weight (g)	57.53	62.80	.35
Parr[2]			
Length (cm)	11.28	11.42	.13
Weight (g)	15.31	15.78	.27

Selection for Delayed Sexual Maturity

F.M. O'Flynn

Higher prices result if salmon are marketed before reaching sexual maturation and the associated deterioration in flesh quality. Thus, when producing a large fish, age at maturity becomes an important economic trait. Selection for rapid growth and late maturation of Atlantic salmon may appear to be incom-

Hatchery manager Rod Carney and student René Gallant display two contrasting types of Atlantic Salmon. The small fish became sexually mature after one sea-winter (grilse), in contrast to the larger salmon that matured after two sea-winters.

patible objectives, since there is some evidence that late maturation is genetically coupled with slower growth rate. In the Biotechnology Strain (85XC), no correlations of significance were found between maturity and freshwater and seawater growth traits, except in the select line where growth rate during the last period in sea water correlated negatively with the incidence of sexual maturity. Estimates of similar correlations are currently being procured for the Saint John River fish, routinely used in the industry.

Three important economic traits in the culture of Atlantic salmon are early smoltification, fast growth rate and low grilsification. In view of the correlations between growth and maturity, multiple-objective selection may be required for the genetic improvement of the economic traits mentioned. A selection index was constructed to increase the percentage of 1+ smolts, the percentage of non-grilse and harvest length.

INDEX = 6.4(PERCENT 1+SMOLT IN THE FAMILY) + 22.5(PERCENT NON-GRILSE IN THE FAMILY) + 3.2(MEAN HARVEST LENGTH FOR THE FAMILY) + 4.0(HARVEST LENGTH OF THE INDIVIDUAL), where the percentages are transformed to arcsine$\sqrt{\text{proportion}}$.

Family information was used to derive the percentages for the various traits. Both family and individual information were used to derive values for harvest length in sea water. The amount of weight given to each trait depends upon its relative economic value, the heritability of each trait and the genetic and phenotypic correlations between traits. The individuals with the highest index scores are then kept for breeding purposes.

A two percent increase in the percentage of 1+ smolts, a 13 percent increase in percentage of non-grilse and 4.5 cm increase in harvest length are the expected gains with a selection intensity of one standard deviation on the index. These results are encouraging, particularly in a strain where grilsification is a problem. A selection intensity of one standard deviation on the index scale yielded 17 out of 39 effective families. This number of parents should result in an increase of slightly less than two percent per generation in the inbreeding coefficient, where random mating excepting full-sib combinations is carried out - a figure that should be acceptable in a long-term program.

Triploidy and Sex Reversals

T.J. Benfey and G.W. Friars

The aquaculture industry is interested in testing the performance of all-female triploid fish with a view to extending the marketing season through the elimination of grilse and, since triploid females are sterile, the alleviation of the perceived problem of cage escapees genetically influencing natural stocks.

Research aimed at these problems has been initiated, where a large sample of first-feeding fry were fed three parts per million of methyltestosterone for 57 days in 1986.

The Biotechnology strain, a stock with a high level of grilsification, was used in the initial work. Five reversed females yielded milt in November, 1989 and were used to fertilize eggs from normal females. Samples of eggs from these same females were fertilized with normal diploid males. A check on ovarian development in the parr confirmed that the sex reversal process yielded all-female progeny.

The heat shock treatment at 28°C for 10 minutes at 20 minutes after fertilization was not highly effective (Table 7), where ten progeny from each mating were checked by flow cytometry for triploidy in the red blood cells.

Table 7. Percentage of triploids following heat shock.

Type of progeny	Type of dam	Groups of parents				
		1	2	3	4	5
Mixed sex	Control	50	10	40	0	-
	Select	70	40	10	30	10
All female	Control	30	22	0	0	-
	Select	70	0	0	10	10

Diploids and triploids from the same single pair mating, where 40 to 70 percent triploids were obtained with heat shock, are compared in (Table 8). The diploids and triploids within a sibship were in competition due to their containment in the same tank, where the heat shock was only partially effective in inducing triploids. Also, triploids competed with diploids from non-heat-shocked eggs when reared in parr tanks containing both types. The heat shock groups produced fewer smolts ($P<.05$) of slightly smaller size, despite larger parr sizes ($P>.10$) when compared to the controls.

Dr. Tillman Benfey, University of New Brunswick, Fredericton, subjects SGRP eggs, in the cylinder, to pressure shock.

Table 8. Weight (g), length (cm) and smoltification performance in progeny derived from control and heat-shocked progeny.

Trait	Treatment	
	Control	Heat Shock
Parr		
Weight	16.11	18.05*
Length	11.27	11.87
Smolt		
Weight	59.45	57.96
Length	17.16	16.82
Smolt (%)	84.0	73.9**

*Difference between control and heat-shock progeny significant at P<.10.
**Differences as described above, significant at P<.05.

Pressure shock has proven more effective than heat shock in inducing triploidy in the treatment of fertilized eggs at early stages of embryonic development. Consequently, this procedure was used on samples of eggs from the 1990 spawning of Saint John River stock, the predominant gene pool in the Bay of Fundy cage industry. Also, the production of reversed females in this stock has been commenced in first-feeding fry in the Winter and Spring of 1991, allowing the possible production of all-female progeny in the next generation. Triploid all-female progeny are sterile. This alleviates the genetic threat of cage escapees to wild stocks, while, at the same time, eliminating the grilse problem in the cage-culture industry.

CULTURE PRACTICES

Evaluation of Single- and Mixed-Family Rearing in Two Stocks of Atlantic Salmon

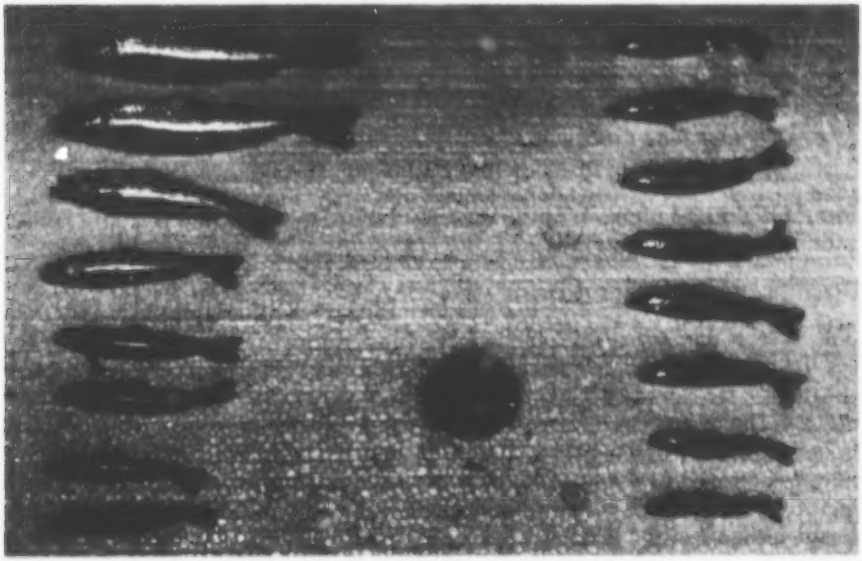
A.R. Hanke

The SGRP has a need for accurate estimates of a family's potential for growth in both fresh and sea water. These estimates are used to determine which family will be permitted to pass its genes to the next generation. Therefore, it is essential that these estimates do not vary with the conditions under which the families are reared. It is for this reason that research is conducted on factors that could alter the rank of those estimates. One such factor is the social interactions that may occur when two or more families are reared together.

During the freshwater phase of rearing, Atlantic salmon families in the SGRP are kept in separate tanks for their first four months of growth, after which these families were combined and reared together. Due to the large num-

ber of families, the small number of fish per family and the size of the tanks, it is not possible to rear fish from every family in every tank. Hence, the estimates of potential for growth are masked when the families are reared together in a tank. This study examined the effect of single- and mixed-family rearing environments on the growth and rank of juvenile Atlantic salmon from a two-sea-winter and a grilse stock. In addition, families were classed as being early or late hatching with this distinction being the basis on which the families were paired to form the mixed-family rearing regime. That is, one early hatch family was reared with a late hatch family (mixed-family tank) and siblings from these families were reared in separate tanks (single-family tank).

The grilse, in contrast to the two-sea-winter stock, had larger size gains over the same four month period (12.6 g, 3.9 cm versus 4.7 g, 2.4 cm), more presumptive smolts (31.2% versus 2.8%) and more sexually mature male parr (8.68% versus .07%). The differences between stocks were also manifested in better growth of the early over the late hatch group in the two-sea-winter but not in the grilse stock. The photograph which follows illustrates the difference between an early- and a late-hatch family from the two-sea-winter stock reared in a common tank.



Variation is apparent both within and between families, where the early-hatch family is on the left and the late-hatch family is on the right. (Photo courtesy A.R. Hanke)

Both stocks showed no difference between the growth of fish from mixed- and single-family tanks; and there was no rearing regime by hatch group interaction. Thus, there was no evidence of competitive depression of late and early hatch groups or a competitive advantage of either hatch group over the other. A significant re-ranking of families-within-hatch groups in the two rearing regimes indicated that the competitive effects were important at the family level, even though not evident at the hatch group level (Figure 3). Therefore, the estimate of a family's breeding value changes between the two rearing regimes, making it necessary to consider the consequences of rearing different groups of families together.

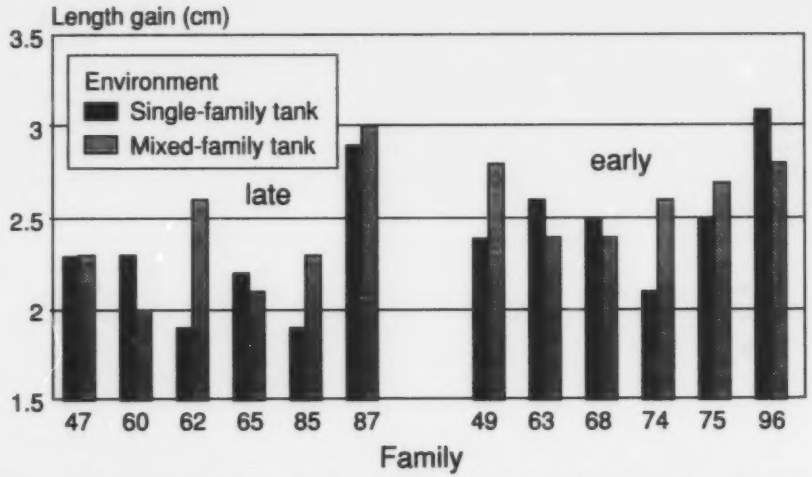


Figure 3. Length gains of early- and late-hatch families from two-sea-winter stock in two environments.

First Feeding Procedures

R.G. Carney

The measurement of the degree days, as expressed by the sum over days of the degees centigrade of the water in the fry tanks for each day, and the visual observation of yolk-sac absorption have generally been the main criteria used in determining when to begin to offer feed to fry. The water content of the fry is now determined in the SGRP laboratory to help assess when feed should first be introduced. As the yolk is absorbed, a higher proportion of the alevin's body tissue is represented by protein and protein-bound water. Good acceptance of food has been observed when the water content of the body is about 78 percent.

Water temperature for incubating alevins is kept between 8°C and 9°C. This temperature is increased to 13.5°C in two stages to coincide with first

feeding. At this time, fry are fed 25 times per day with a photoperiod of 20 hours of light for about two weeks prior to gradual reduction to about 16 hours when transferred to outside tanks.

Survival at the alevin and fry stages has improved during the last two years, following adherence to these procedures.

Consultation with Diagnostic and Health Services

R.G. Carney

Fish health services for the SGRP were carried out in co-operation with five agencies, both governmental and private. These agencies were the DFO Fish Health Service Unit in Halifax, the Moore-Clarke (Canada) facilities in St. Andrews, the Department of Fisheries and Aquaculture (DFA) in St. Stephen, the Atlantic Veterinary College in Charlottetown and the University of New Brunswick (UNB)/Research and Productivity Council (RPC) Fish Health Service in Fredericton. Services performed included the screening of milt and ovarian fluid from broodstock for bacterial kidney disease and the monitoring of stocks being moved to marine cage sites for carriers of furunculosis.

Diagnostic procedures confirmed fungal infections during sac-fry development and a parasitic infestation, *Ichthyophthirius multifilis*, was identified in a group of parr during 1990/91. Recommended treatments with formalin (1:4000 for 1 hour) alleviated both of these problems.

Strain and Photoperiod Effects on Fall Growth of Parr

G.W. Friars, C.G. Soto, I. McMillan and M. Quinton

Work reported by Hanke (SGRP Annual Report, 1988/89) indicated that certain families responded better than others when growth was stimulated by an extended photoperiod during the Fall. That research used the Biotechnology Strain (85XC). An opportunity to test the Biotechnology Strain simultaneously against Saint John River stock (Strain 84JC) arose, and the details of that experiment are outlined here.

Fifteen parr from each of ten families (150 fish) were placed in each of two 1.1 m diameter tanks for each of the two strains. Following a gradual decline in photoperiod from 20 to 12.75 hours from April 13 to September 7, two photoperiods were established as follows:

1) Natural day length declining from 12.75 hours to 8.57 hours on Dec. 14.

2) Extended photoperiod of 16 hours per day.

Six replicated tanks of each of the two strains in each of the two photoperiod regimes required a total of 24 tanks. Thirty fish from each tank were weighed and measured for length at the start of the experiment on September

Table 9. Least square means of length (cm), weight (g) and condition factor [(weight/length^3) x 100] in the Biotechnology and SJR Strains in natural (12.7 - 8.7 h/day) and extended (16 h/day) photoperiods.

		Trait		
Strain	**Photoperiod**	**Length**	**Weight**	**Condition factor**
Biotechnology	Natural	9.67 (1.38)[1]	9.76 (5.18)	1.0257 (.0259)
	Extended	11.05	14.94	1.0516
SJR (Strain 84JC)	Natural	9.54 (1.38)	9.41 (4.68)	1.0227 (.0056)
	Extended	10.92	14.09	1.0283
	Interaction[2]	0.00	0.50*	.0203

[1]Differences between treatments in brackets.
[2]Interaction of strain by photoperiod (difference between strains of differences between photoperiods).
*Interaction significant at P<.05.

7. The weight and length data indicated that random sampling between treatments had been accomplished. All fish were weighed and measured on December 13 and 14. The means reveal that the Biotechnology Strain fish were slightly larger than those of the SJR Strain (Table 9). Also, the extended photoperiod, accompanied by additional feeding during the extended photoperiod, increased both weight and length. Bimodality in the length and weight distributions were not readily apparent, possibly due to the stage of development in crowded conditions and the mixtures of family distributions. The interaction of strain by photoperiod for weight but not length is interesting and, although not significant (P>.05), is reflected in the condition factor. The response to the extended photoperiod was .5 g greater in the Biotechnology Strain than in the SJR fish. This result parallels the earlier findings with families within a strain, indicating a genetic ability to respond to an extended photoperiod (SGRP Annual Report 1987/88).

Evaluation of a Plastic Grid System as an Artificial Substrate for Sac Fry

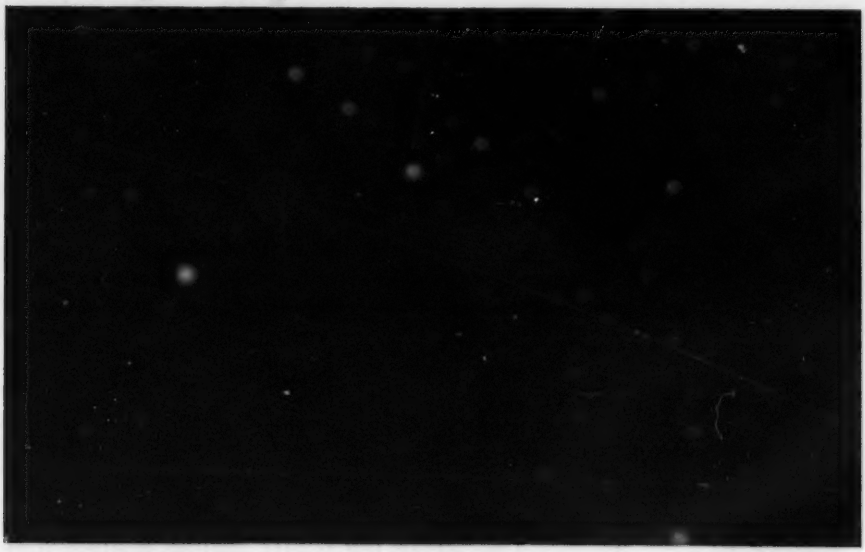
F.M. O'Flynn and R.G. Carney

Studies by Hortle (Department of Sea Fisheries, Tasmania, Technical Report 17, 1987) have shown that fry reared on plastic grids were significantly larger at first feeding, had lower mortality and accepted food more readily than

contemporaries reared without grids. The aim of this study was to evaluate the effectiveness of a plastic grid system as an artificial substrate for SGRP sac fry.

On January 3 and 4, 1991, eggs from the 1990 year class were shocked and counted for each of the 45 families. Earlier, at spawning, eggs from each family were split into two experimental units. After shocking, eggs from one experimental unit were incubated in standard Ewos hatching troughs and baskets. Eggs from the other experimental unit in each family were incubated in Ewos hatching troughs and baskets containing the plastic-grid (height 10 mm; grid size 10 x 10 mm). After ten days, approximately 100 percent hatch was observed in both groups.

On February 18, the fry were transferred to 1.1 m diameter hatchery tanks. Three weeks later the fry started first feeding. Percent survival was calculated from hatch to time of transfer, for each type of hatching system, for 45 families. The mean survival rate for the hatching troughs and baskets with no plastic grid was 85 percent in contrast to 79 percent where the plastic grid was used as an artificial substrate. A t-test was performed on the angular transformation of percent survival ($\sin^{-1}\sqrt{\text{proportion surviving}}$). The six percent difference in survival between the two types of hatching systems was found to be insignificant ($P>.05$). The artificial substrate made it difficult to pick mortalities which accumulated between the plastic grid and the bottom of the hatching trough and this enhanced the transmission of fungus. Thus, mortality in the troughs with plastic grids was higher.



Sac fry in hatching tray containing a grid.

In June 1991, before the fry are moved to the outside tanks, length and weight will be measured and survivability calculated. Results will be compared to determine if there are any differences in performance after first feeding between the two types of hatching systems.

FIBREGLASS VERSUS CONCRETE REARING TANKS FOR PARR AND SMOLT

There is a general tendency for the size of smolts and smoltification rate to be higher in fibreglass than in concrete tanks (SGRP Report Series 109). The reasons for the apparent improved performance in fibreglass relative to the concrete tanks are not readily apparent. The three reports under this heading deal with different approaches to investigating the cause for the difference in tank types.

Aluminum and Silicon Content of Water in Concrete and Fibreglass Tanks

C. Exley, F.M. O'Flynn and M.W. Groom

Fish sublethally exposed to many different toxicants often show reduced appetite, the extent of this being related to the nature and duration of the exposure and the potential for some adaptation towards the toxicant. In this way aluminum could affect growth, although there is no evidence of silicon having such an effect. In addition aluminum has been shown to both interfere with calcium deposition in the bones of fish and exacerbate this condition further, to enhance demineralisation of bones. These conditions are possible during long exposures to sublethal concentrations of aluminum.

Water samples were taken from three concrete and three fibreglass tanks commencing on November 7, 1990. Densities ranged from approximately 2,470 to 2,582 fish per tank. Sampling took place on the same day of the week, at the same time, for 12 weeks. The samples were stored at 4°C and shipped monthly to Stirling University, Scotland for analysis.

The mean concentration of aluminum was lower in the fibreglass (.44 μM/L) than in the concrete tanks (.46μM/L). However, this difference was non-significant ($P>0.05$). The aluminum concentration decreased, but not significantly ($P>0.05$), during November and December (Figure 4).

The mean concentration of silicon was significantly lower ($P<0.01$) in the fibreglass (6.6μM/L) than in the concrete tanks (8.0μM/L). The silicon leaching significantly decreased ($P>0.01$) in fibreglass tanks compared to concrete tanks during early December (Figure 4).

It appears that temperature or other seasonal variables affected the rate of leaching. At lower temperatures, during the Winter months, aluminum and silicon concentrations in the water decreased (Figure 4). Silicon leaching was

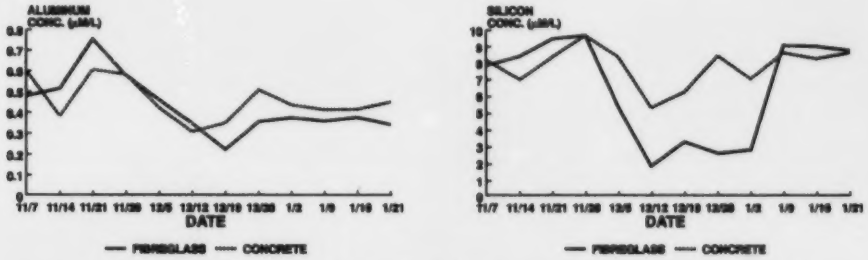


Figure 4. Variations in aluminum and silicon concentrations over time in concrete and fibreglass tanks.

considerably less in fibreglass tanks than in concrete tanks. It will be interesting to monitor chemical concentrations in the water over different seasons, especially in the late Summer and early Fall when physiological changes related to smoltification occur. Also, the determination of levels in the incoming water could enhance future studies.

Noisier Environments May Retard Smoltification in Atlantic Salmon

J.M. Terhune and S.D. Turnbull

Earlier work indicated that higher noise levels existed in concrete compared to fibreglass tanks (SGRP Annual Report, 1989/90). The following is a report of a preliminary study conducted at UNBSJ with a view to investigating the hypothesis that noisier environments retard presumptive smoltification.

Five sets of 530+ Atlantic salmon parr from the same full-sib family, provided by the SGRP, were reared in glass aquaria. The aquaria had a continuous flow and aeration was accomplished in a single header tank. The tanks were covered by dark grey, plexiglass sheets. The fish were fed a standard commercial mixture at approximately four percent body weight per day. Natural daylight was provided via a window. Every effort was made to treat the fish in each aquarium in a similar manner. Two tanks (1 and 5, at each end of the rows of five) served as controls. A white noise generator supplied an amplifier and loudspeaker in Tank 2. In Tank 3, a relay attached to a metal box, was activated for 9 sec every 84 sec. This produced a "click" both at the onset and end of the activation period. In Tank 4, the sound source was a continuous siren which produced a loud tone which regularly alternated between 1.0 and 1.5 kHz. The noise sources in Tanks 2, 3 and 4 were all contained in two plastic bags for waterproofing. The study began on July 11, 1990 and was terminated January 7, 1991. Each fish was weighed and measured. Smoltification was presumed if the fish was silvery in colour and had lost the parr marks. A few mortalities occurred and a few fish jumped out of Tank 1 when the plexiglass cover was inadvertently left askew.

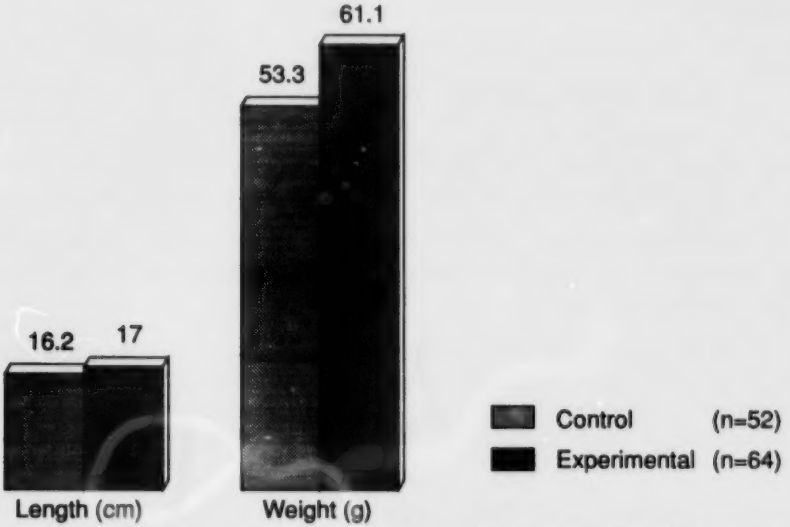
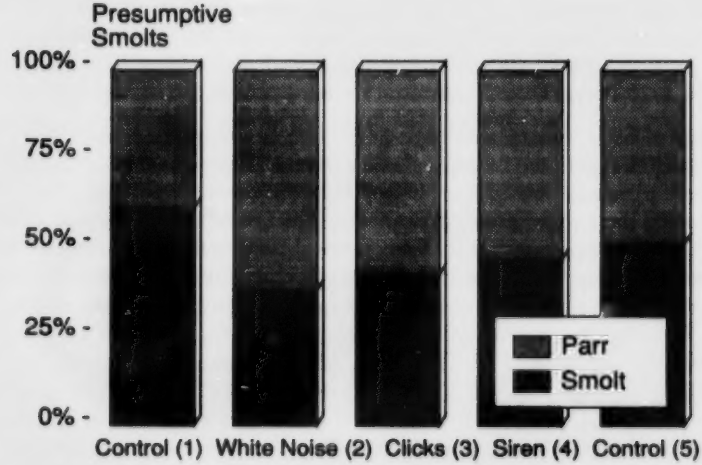


Figure 5. Mean lengths and weights, standard deviations (SD) and numbers of fish (n).



Presumptive Smolt %	61	38	42	46	50
Parr (No.)	16	31	31	26	26
Smolt (No.)	25	19	23	23	27

Figure 6. Presumptive smoltification percentage and numbers of parr and presumptive smolts in each tank.

There was a significantly greater proportion of smolts in the control tanks (1 and 5 summed) than in the noise tanks (2, 3 and 4 summed); chi square 3.848, 1 d. of f., $P<0.05$ (Table 10.). The only significant difference on a tank by tank basis was between Tank 1 and Tank 2 (chi square 4.762, 1 d. of f., $P<0.05$).

The presumptive smolt in the experimental tanks were longer ($F=6.525$, 1,114 d. of f., $P<0.05$) and heavier ($F=8.182$, 1,114 d. of f., $P<0.01$) than in the two control tanks (Fig. 5). The increased size in the experimental tanks could have been due to the decreased density.

The noise levels were noticeably higher in the experimental tanks. The fish in Tank 4 tended to avoid the immediate vicinity of the siren. Differences between tanks could not be properly measured using existing equipment.

Within the limits of the experimental situation, the hypothesis was supported; smoltification rates were higher in the quieter set of tanks (Fig. 6). The trade-off appears to be fewer but larger smolt in the noisier tanks, associated with food availability. The smolt in the experimental tanks had fewer competitors of similar size. The results of this pilot project indicate that further research into the relationships between increased noise and presumptive smoltification is warranted.

Physiological Indicators of Smolt Development in Fibreglass and Concrete Tanks

R.L. Saunders

This project was designed to find biological bases for the observed difference in production of yearling smolts from the fibreglass and concrete rearing tanks at the Salmon Research Centre.

The hypothesis to be tested is that smolt development is impaired or delayed in fish in concrete as compared with those in fibreglass tanks. Smolt development is assessed by performance in a salinity tolerance test which measures percent survival 96 hours after direct transfer from fresh to hypersaline (37.5%) sea water and by gill Na^+-K^+ AtPase activity.

Four groups are being studied in this way at intervals from late February to mid-May. Two groups of 10 fish at each test time have lived since the previous Summer in fibreglass and concrete tanks respectively; the other groups were transferred reciprocally between the two tank types at the beginning of the experiment. Ten and eight fish per group are used in salinity tolerance and gill ATPase assays respectively. Individuals are identified by Passive Integrated Transponder (PIT) tags and the assessments of salinity tolerance and gill ATPase activity are conducted without knowing to which groups individuals belong.

Feed Deprivation during Winter-Spring to Reduce Grilse Maturity

R.L. Saunders

Research in Scotland has shown that reduced rations during certain periods in Winter-Spring can lead to reduced incidence of grilse the following Autumn, probably owing to reduced stores of energy and a "decision" to postpone sexual maturation. The purpose of our research is to learn if the strategy will work in the Bay of Fundy environment and to develop a technology for the local industry.

Pre-smolts from a SGRP grilse strain (Biotechnology) will be used in an experiment to study energetic changes in lipid levels and final maturity response to various strategies of food deprivation during Winter-Spring, 1992. The study is funded partly by the Atlantic Fisheries Adjustment Program. Connors Bros. Aquaculture Ltd. will rear 21,000 fish divided among four standard sea cages. A smaller version will be run using four tank groups of 200 each at the DFO Biological Station, in order that sampling for energetic analysis and growth rate can be done on a regular basis, not permissible at the cage site. The fish in the lab experiment were PIT tagged, allowing consideration of growth rate during the entire experiment (May, 1991 - November, 1992) in relation to sexual maturation. Use of the same feeding protocols in the sea cages and in the lab will provide a degree of replication.

INFORMATION EXCHANGE

S.E. Young-Lai

The communication of information gained from technological innovation is a vital component of research and development. The goal of the SGRP is to understand Atlantic salmon genetics for the purposes of enhancing wild stock and breeding fish better fitted to the needs of the aquaculture industry. The transfer of knowledge to the people concerned with these issues is a top priority.

Communication among SGRP and other scientists, angling and aquaculture representatives and the general public occurs at many levels. Contact by telephone, correspondence, visits, service on scientific and advisory committees, review of manuscripts and theses, and participation in local, national and international conferences, seminars and workshops all represent avenues for information exchange. Articles in scientific journals, technical reports and the popular press disseminate research findings.

Some of the highlights of the SGRP's involvement in information exchange in 1990/91 included participation in a number of national and international conferences. Topics included conservation of fisheries genetic resources (Pitts-

burgh, Pennsylvania), problems in Atlantic salmon husbandry (Rockport, Maine), genetics applied to salmon production (Edinburgh, Scotland), ecological and genetic implications of fish introductions (University of Windsor, Windsor, Ontario), the genetics of stress (University of New Brunswick), Atlantic salmon broodstock development (Bedford, Nova Scotia), fish health (Charlottetown, Prince Edward Island) and Atlantic salmon nutrition (St. Andrews, New Brunswick). Representatives from the SGRP participated in the World Aquaculture '90 meetings in Halifax, the annual Aquaculture Association of Canada meetings and Atlantic Aquaculture Trade Show in St. Andrews in June. New visual displays depicting the role of the SGRP were developed in 1991 and are being used at sportsman's and trade shows.

A workshop on Broodstock Development, sponsored by the SGRP in cooperation with the New Brunswick Salmon Growers' Association (NBSGA), highlighted the place of triploids in aquaculture, gains from selection, diseases and other matters of concern to growers at ASF's new conference facilities on February 27, 1991. Speakers included Dr. John Anderson (ASF), Dr. Tillmann Benfey (UNB), Dr. Richard Saunders (DFO), Mr. John Cornick (DFO), Dr. John O'Halloran (DFA), Dr. John Bailey (SGRP), Mr. Alex Hanke (SGRP), and Dr. Gerry Friars (SGRP). Mr. Brian Rogers (Sea Farm Canada, Inc.) and Mr. George Wolf (Jail Island Salmon, Ltd.) chaired the morning and afternoon sessions respectively. Mr. Gene Henderson (NBSGA and ASDDF) chaired and participated in a panel session which dealt with industry concerns in broodstock development and which involved Mr. Bill Robertson (Connors Bros. Ltd.), Ms.

SGRP broodstock development workshop participants. (Photo courtesy Bill McMullon)

Shirley Roach (Sea Farm Canada, Inc.), and Mr. Garnet Matheson (Aquaventures, Ltd.).

Sixteen publications appeared in print in 1990/91, including the second in a series of newsletters published for the Bay of Fundy salmon growers. The Chief Scientist and Geneticist visited growers' aquaculture sites for discussions again this year.

In the area of staff development, two SGRP staff members, Roy Rogers and Michael Groom, began correspondence course work in salmonid incubation and salmonid diseases from North Island College, Campbell River, British Columbia.

As in past years, the SGRP acted as a training ground for future salmon research and salmon aquaculture specialists. Students from the New Brunswick Community College Aquaculture Technician Training Program participated in practical sessions at the Salmon Research Centre throughout the year. One UNB graduate student, Fiona O'Flynn, completed a Masters' thesis based on the development of a selection index and another, Alex Hanke, continued to pursue doctoral studies into the effects of single-and mixed-family rearing.

The Atlantic Salmon Centre, ASF's interpretive centre and aquarium, continued to play a major role in the distribution of information on Atlantic salmon biology, breeding and husbandry to summer visitors.

STEERING COMMITTEE

R.H. Cook, Department of Fisheries and Oceans, St. Andrews, N.B. (Chairman)

J.H. Allen, Huntsman Marine Science Centre, St. Andrews, N.B.

J.M. Anderson, Atlantic Salmon Federation, St. Andrews, N.B.

B.D. Glebe, National Research Council of Canada and Huntsman Marine Science Centre (HMSC), St. Andrews, N.B.

E.B. Henderson, New Brunswick Salmon Growers Association, St. George, N.B.

Ian Hamilton, Aqua Fish Ltd., St. George, N.B., to November 28, 1990.

J.D. Kershaw, Department Fisheries and Aquaculture, St. Stephen, N.B.

D. MacMinn, Department Fisheries and Aquaculture, Fredericton, N.B.

L. Parsons, Jr., Albuquerque, N. M.

J.A. Ritter, Department Fisheries and Oceans, Halifax , N.S.

G. Wolf, Jail Island Salmon Ltd., St. George, N.B., from November 28, 1990.

SCIENTIFIC ADVISORY COMMITTEE

G. J. Farmer, Department Fisheries and Oceans, Halifax, N.S. (Chairman)

T.J. Benfey, University of New Brunswick, Fredericton, N.B.

R.W. Doyle, Dalhousie University, Halifax, N.S.

P.E. Ihssen, Ministry of Natural Resources, Maple, Ontario

H.L. Kincaid, U.S. Fish and Wildlife Service, Wellsboro, PA

R.L. Saunders, Department Fisheries and Oceans, St. Andrews, N.B.

PERSONNEL INVOLVED WITH SGRP IN 1990/91

1. Full time SGRP staff

G.W. Friars, Chief Scientist
J.K. Bailey, Geneticist
R.G. Carney, Hatchery Manager
C.G. Soto, Research Technician (until October 19, 1990)
F.M. O'Flynn, Research Assistant (from January 1, 1991)
J.A. Dickson, Technician (from May 28,1990)
A.E. Fulton, Technician (from August 13, 1990)
M.W. Groom, Technician
C.A. James, Secretary (from May 27, 1991)
D.A. Johnson, Technician
R.R. Rogers, Technician
S.E. Young-Lai, Secretary (until May 6, 1991)

2. Permanent ASF staff allied to SGRP

J.M. Anderson, Vice President, Operations
B.E. Day, Vice President, Finance and Administration
P.V. Frankland, Technician (from December 17, 1990)
J.W. Gibson, Technician
E.H. Jensen, Assistant Hatchery Manager (to Sept 2, 1990)
D. Wylie, Building, Grounds and Vehicles Supervisor
I. Wylie, Custodian

3. Graduate students

F.M. O'Flynn (until May 30, 1990) and A.R. Hanke, UNBSJ graduate students under G.W. Friars' co-supervision

4. Temporary ASF, part-time SGRP

Rhonda Anderson, Norman Talbot Mais Intern (July and August, 1990)

5. Cooperative researchers

Many of the cooperative researchers have already been noted as authors or co-authors of sections of this report. These are:

T.J. Benfey, University of New Brunswick
R.D. Doyle, Dalhousie University
C. Exley, Stirling University
A.J. Harrington, University of Guelph
C.M. Herbinger, Dalhousie University
I. McMillan, University of Guelph
R.D. Moccia, University of Guelph
M. Quinton, University of Guelph
C.G. Soto, Dalhousie University
J.M. Terhune, University of New Brunswick. Saint John, N.B.
S.D. Turnbull, University of New Brunswick, Saint John, N.B.

The following are cooperative researchers involved in projects not currently at the reportable stage:

G.B. Bacon, Research and Productivity Council
M.D. Burt, University New Brunswick
D.M. Blouw, St. Francis Xavier University
R.R. Claytor, Depatment Fisheries and Oceans, Moncton
L.W. Crim, Memorial University
G.J. Farmer, Department Fisheries and Oceans, Halifax
M.M. Ferguson, University of Guelph
E.B. Henderson, New Brunswick Salmon Growers Association
W.H.W. Lynch, University New Brunswick
M.A. McNiven, University, Prince Edward Island
B. MacKinnon, University New Brunswick
G. Olivier, Deptment Fisheries and Oceans, Halifax
E. Verspoor, Department of Agriculture and Fisheries for Scotland
J. Volpe, University of Guelph

6. Employment and Immigration Canada Section 25 Job Creation Program

Donny Daley	Shawn Jones	Dennis Smith
Allana Essency	Allen Scott	Paul Sullivan

7. New Brunswick Community College Aquaculture Technician Training Program students

Joanna Chase	Russ Hawkins	Ted Reader
Paul Fox	Judy Kernighan	Ken Ross
Brent Galbraith	Theresa Lamb	Francois Roy
Réné Gallant	Tammy McLean	Guy Sorrel
Kelly Hamilton	John Munro	Sue Willis

8. Challenge '90 Program

Ron Manuel Tim Whitters

9. Casual SGRP Assistance

Shelley McCurdy

10. Research Associates

B.D. Glebe, NRC/HMSC, St. Andrews
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ACKNOWLEDGEMENTS

The authors of the different sections of this report are indebted to the many reviewers who made valuable editorial contributions. Funding for the research has been provided by DFO, ASF, NBSGA, National Research Council, UNB, the Vaughan Scholarship and the Norman Talbot Mais Internship.

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The Atlantic Salmon Federation (ASF) is an international non-profit organization which promotes the conservation and wise management of the Atlantic salmon and its habitat through education, enhancement, restoration, research and international cooperation.